



ASIA-PACIFIC TELECOMMUNITY

The 5th Meeting of the APT Conference Preparatory
Group for WRC-2012 (APG2012-5)

Document No :

APG2012-5 /INF-AUS7

29 August – 03 September 2011, Busan, Rep. of Korea

22 August 2011

REPORT ON EXPERIMENTAL ACTIVITIES UNDERTAKEN FOR WRC-12 AGENDA ITEM 1.23

by

Australia

Agenda item 1.23:

to consider an allocation of about 15 kHz in parts of the band 415-526.5 kHz to the amateur service on a secondary basis, taking into account the need to protect existing services

1. Introduction

Some administrations in all three ITU Regions have authorised operation by amateur service operators within their jurisdiction, either to a limited number of amateurs through an experimental license or special temporary authority, or to the general amateur population through a national authorisation. Such authorisations vary in the allowed frequencies and power for each station. This Report describes the experimental activities recently undertaken in Australia in the band 505-515 kHz.

This band is not presently available to the amateur service in Australia; however, the Wireless Institute of Australia (WIA) was issued with experimental licences that permitted transmissions in the band 505-515 kHz. The purpose of the transmissions was to allow studies to be undertaken to inform the Australian Administration's preparations for WRC-12. Principal objectives were to demonstrate that practical and useful transmissions could be made from a typical amateur service facility without causing interference to nearby MF broadcast receivers or to existing users of the band 415-526.5 kHz. The transmissions also permitted assessment of the achievable coverage under day-time, ground-wave and night-time, sky-wave propagation conditions. The following pages describe the experimental operations undertaken in Australia. It is anticipated that the results of the studies may form a contribution to the work of WRC-12.

1.1 Experimental operation in Australia

The experimental licences that were issued to the WIA authorised transmissions with the following characteristics:

Table 1: Allowed transmitter characteristics:

Mode of operation	Morse Telegraphy	PSK-31	FSK-31	MSK-31	Other Digital Modes
Frequency band (MHz)	0.505-0.515	0.505-0.515	0.505-0.515	0.505-0.515	0.505-0.515
Emission designator	150HA1A	62H0J2B	62H0F1B	62H0G1D	1K00D1D
Authorized eirp.(watt/dBW)	25/14	25/14	25/14	25/14	25/14

During the period of the experimental activities, five stations (two in Australian Capital Territory and one in each of New South Wales, Victoria and South Australia) operated with a variety of transmitter installations using both home-made and commercial equipment. Experimental transmissions occurred on both an ad hoc and scheduled basis. The experimental work performed under the licence conditions included:

- Normal on-off keyed Morse code (A1A modulation).
- Slow speed (QRSS) on-off and frequency shift keyed Morse code.
- Weak Signal Propagation Reporter (WSPR) mode.
- Beacon transmissions using a variety of ‘sound card’ digital modes.
- A limited number of two-way contacts.
- Development of equipment; transmitters, receivers and antenna systems.
- Internet enabled receivers.
- Picture transmission.
- Measurement of ground wave field strength and estimating station effective radiated power.

The following pages describe the work in more detail.

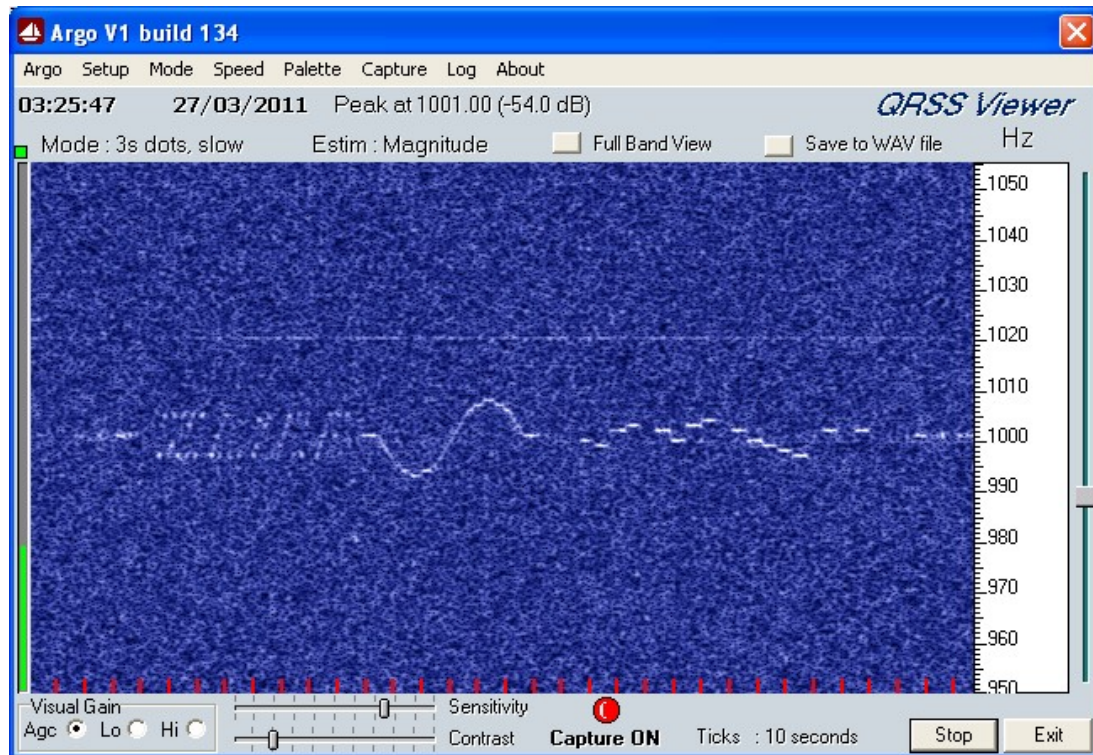
1.2 CW Beacon Transmissions

Normal on-off keyed Morse code (A1A modulation): Daytime reception of normal Morse code signals extended out to several hundred kilometres, while night time reception extended to approximately 2000 km. Amateur operator AX2VKW (VIC) operated a CW beacon on 507 kHz over most weekends for the duration of the experimental activities. This beacon was very useful for the development of receiving capability as it provided a stable off-air signal for testing. Other stations operated beacons using a variety of modes on an ad hoc basis and these were useful in raising awareness of various digital modes.

1.3 Slow Speed CW Transmissions

Slow speed (QRSS) on-off and frequency shift keyed Morse code and Hellschreiber are simple modes often used for weak signal communications. These modes allowed trans-Tasman reception of signals; with signals from New Zealand amateur MF beacons being regularly heard in Australia and a more limited number of reports of reception of Australian MF signals in New Zealand, a distance of approximately 2500 km. Figure 1 shows typical results obtained using QRSS3 mode (Morse code using 3 second dot length):

Figure 1: The signal from a New Zealand station (ZL1EE) received in Canberra by AX2VKZ. ZL1EE was using a 10 W transmitter at the time. Reception was by means of an active whip and receive converter to the 3.5 MHz band. These modes have the advantage that non-linear transmitter power amplifiers can be used, such amplifiers are easy to construct and are very efficient.



1.4 Weak Signal Propagation Reporter (WSPR)

WSPR mode uses a slow speed multi-frequency shift transmission with Forward Error Correction (FEC) coding; reception reports are automatically given in real time via the internet. Multiple stations operate in a 200 Hz frequency interval using a time division multiplex system synchronised to a two minute time interval. Signal reports contain unambiguous transmitter identification and reliable signal-to-noise ratio measurements which are useful in assessing propagation conditions across various paths. This system allows a time series of signal reports to be created which provides useful data for on-going analysis of propagation conditions.

A network of such stations could monitor propagation over a wide area and possibly add to our knowledge of short and long term variations as well as local and regional propagation changes.

Typical examples of the results obtained with such techniques are shown in Figures 2 and 3:

Figure 2: This plot shows the changes in WSPR reported signal to noise ratios over a distance of 917 km (Canberra, ACT to Nairn, SA). The plot was produced from data obtained from the WSPR database.

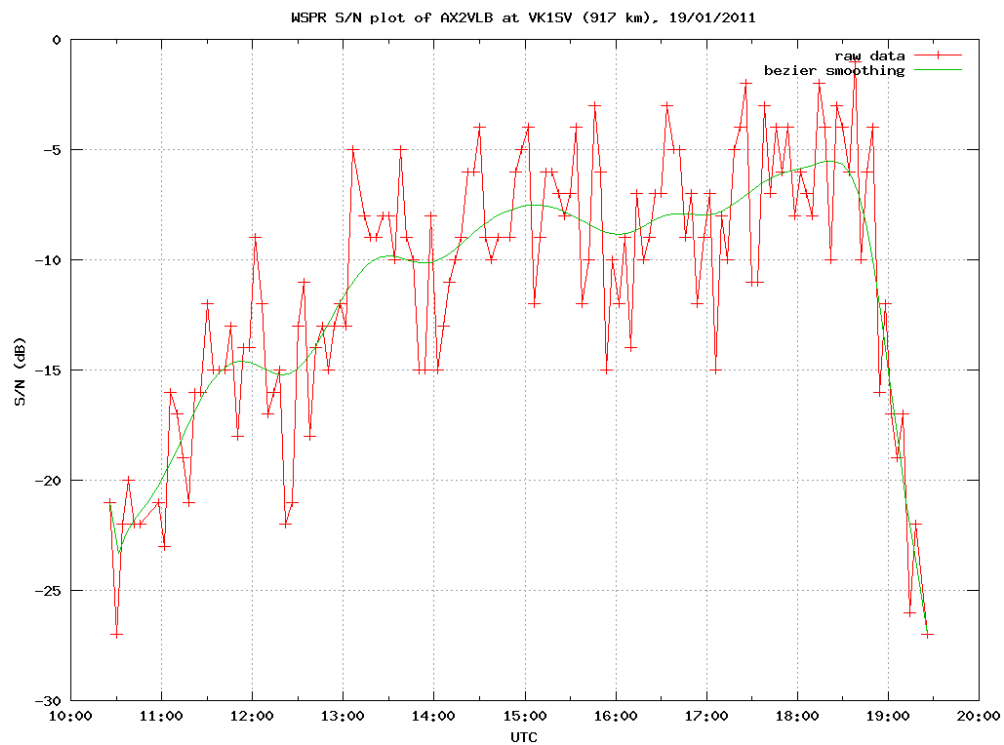


Figure 3: AX2VKY (ACT) and AX2VLA (NSW) are ground wave distance stations @ about 140 km distance from the receiver. AX2VLB (SA) sky wave distance is about 1060 km.

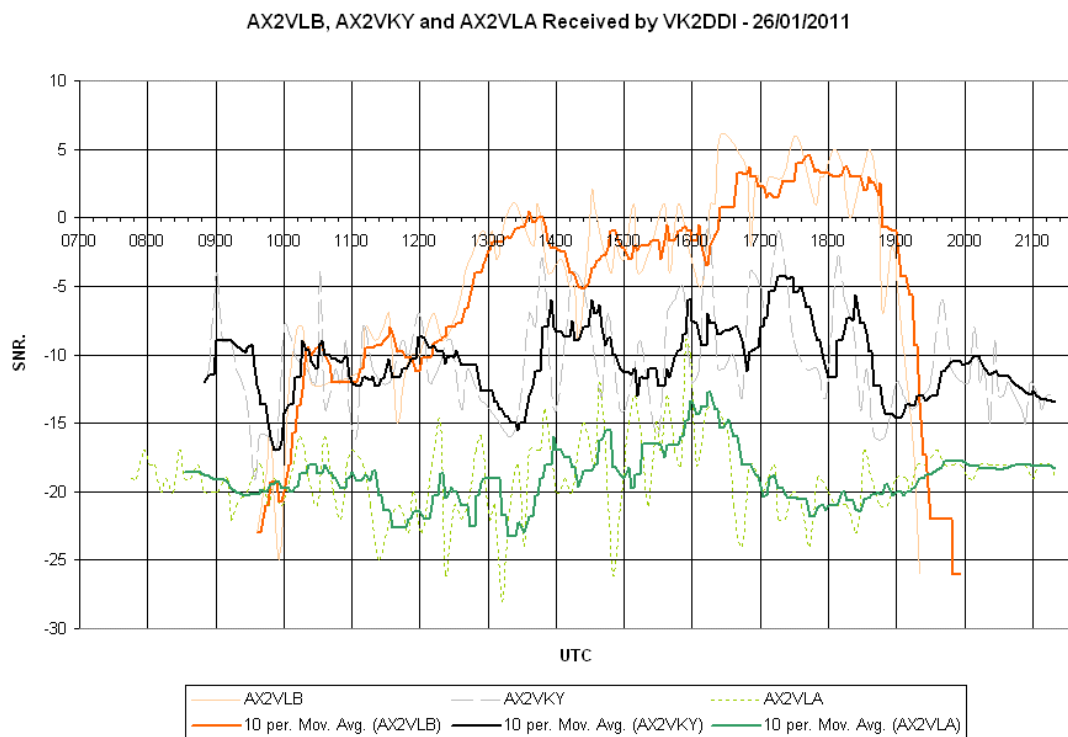
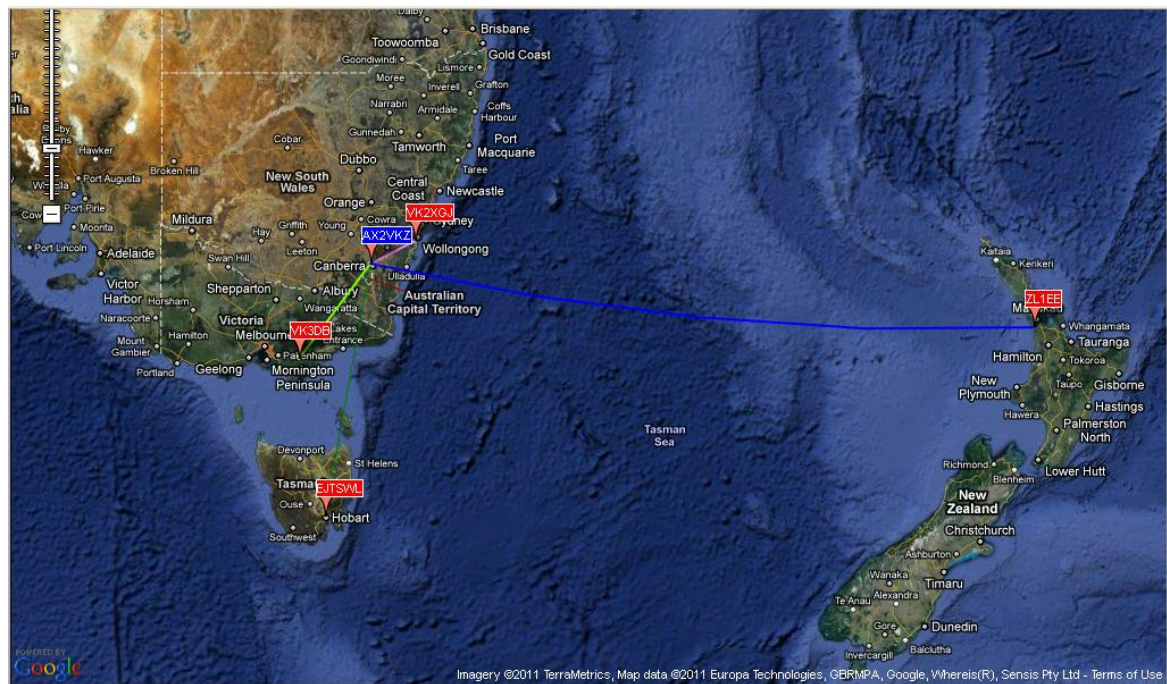


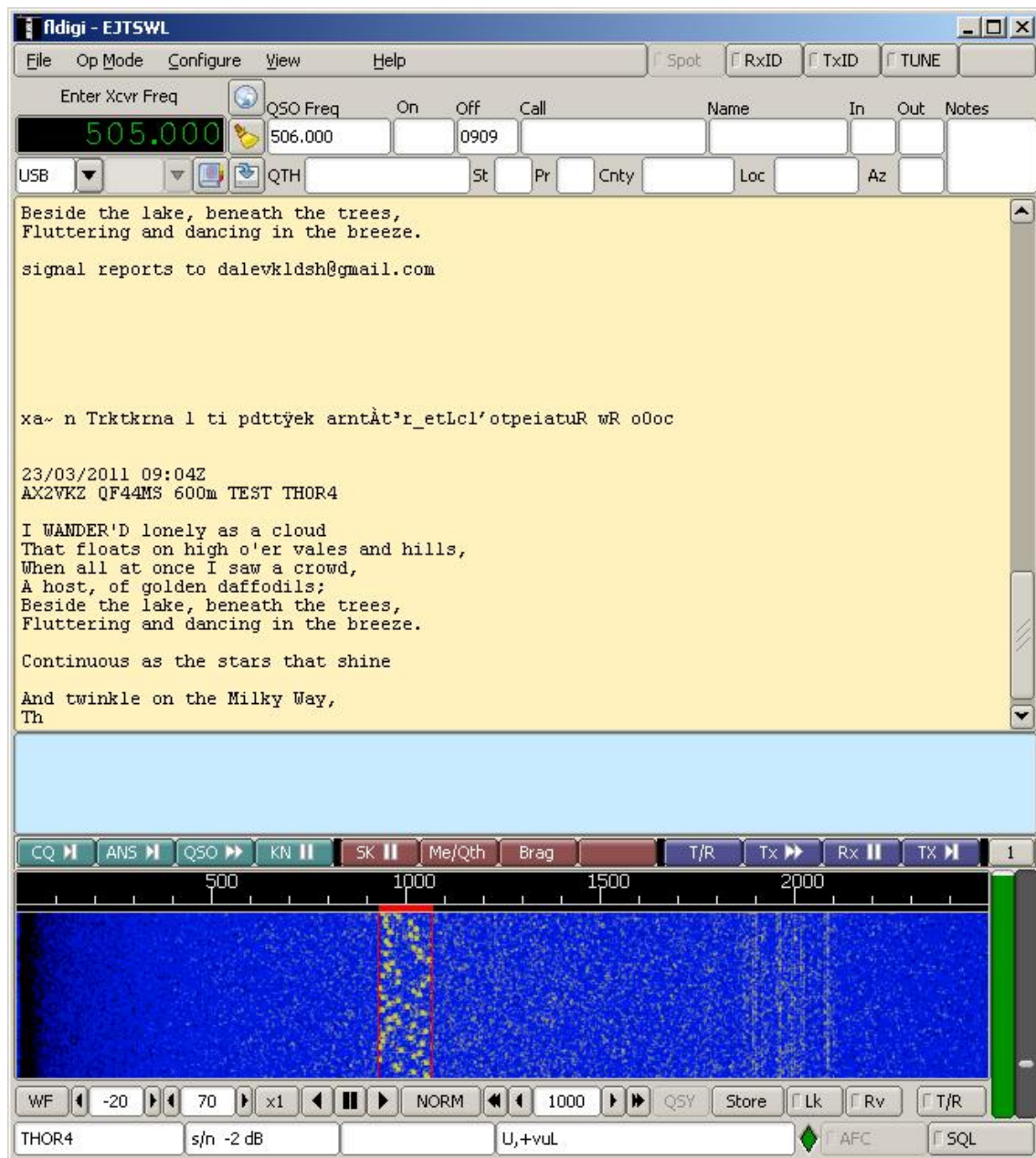
Figure 4: A real time map display of test transmissions paths on 511 kHz available via the WSPR website



1.5 Digital modes

Beacon transmissions using a variety of ‘sound card’ digital modes, with and without FEC were implemented. These beacon transmissions have shown the capability of digital modes for the reliable dissemination of text information that may be useful in disaster or emergency situations. Day time ranges of approximately 200 km and night time ranges up to approximately 1000 km were achieved. Longer range reception is likely and it is thought that results were limited by a lack of suitable receiving stations. Figure 5 show the results from a typical test transmission:

Figure 5: The text was transmitted using THOR4 mode from a 50 watt transmitter and reliably received over a distance of 861 km; Canberra, ACT to Moonah,TAS.



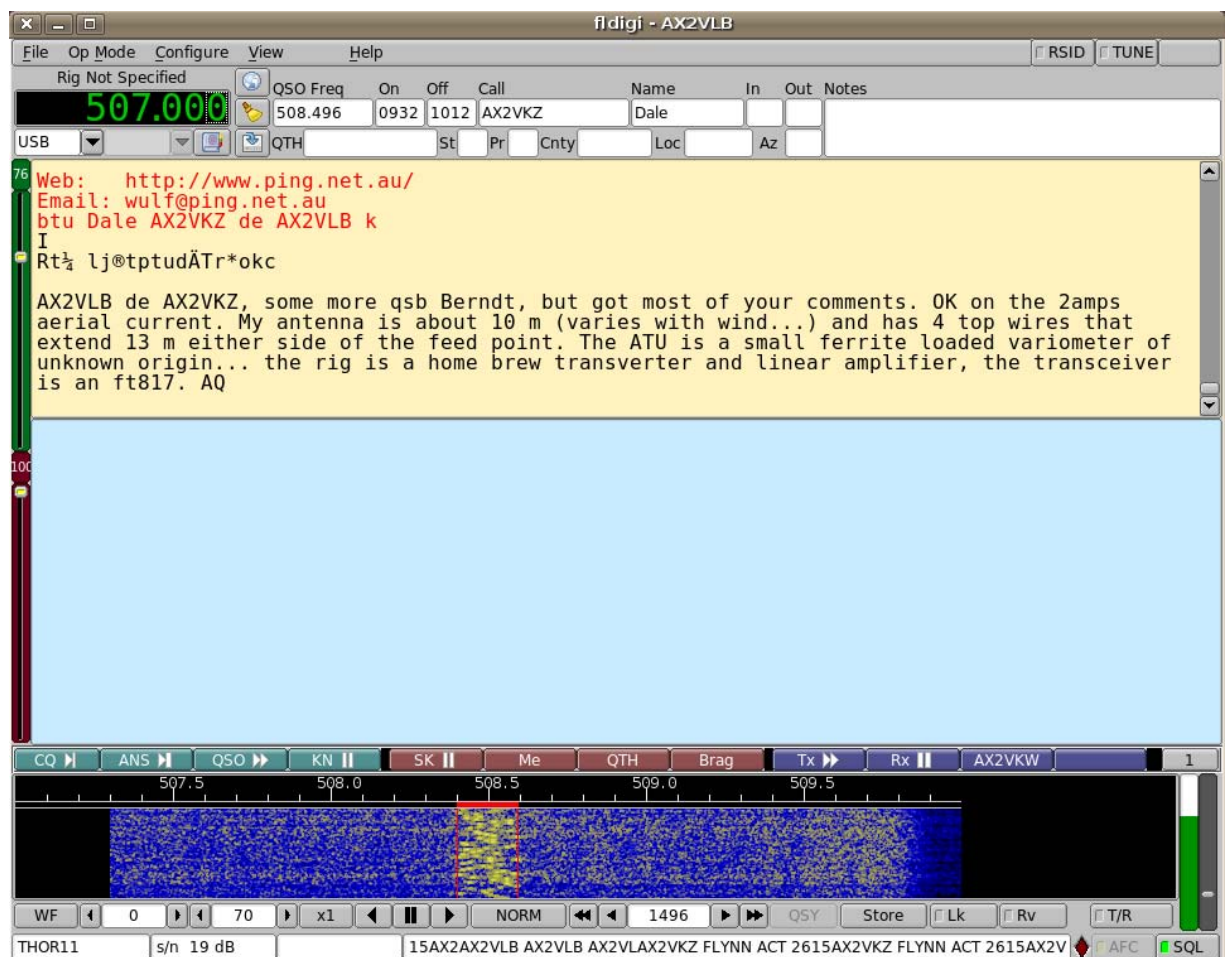
1.6 Two way contacts

A limited number of two-way contacts using both Morse code and keyboard modes have shown that reliable two-way communications can be achieved over paths up to at least 1000 km long at night.

Several two-way CW contacts have occurred; AX2VKW (VIC) and AV2VKZ (ACT) over a distance of ~440 km and between AX2VKW (VIC) and AX2VLB (SA) over a distance of ~650 km.

For keyboard modes, modest data rates of approximately 40 to 50 words per minute have been used with 100% correct copy over long distance paths (Canberra, ACT to Nairn, SA). Figure 6 shows part of a two way contact:

Figure 6: Part of a two way contact using THOR11 mode over a distance of ~917 km between stations in Canberra, ACT (AX2VZK) and Nairn, SA (AX2VLB). AX2VLB transmitter output was 100 watts and AX2VKZ transmitter output was 50 watts. THOR11 is a keyboard mode that runs at about 50 words per minute.



1.7 Development of transmitters, receivers, antenna systems and interference mitigation

The experimental licences allowed a significant amount of expertise to be developed in the 'trials and tribulations' of setting up and operating a MF station in a typical urban environment. Significantly, there were no known reports of interference to radio or television broadcast reception or other services.

Typical transmitter powers were in the range of 10 to 100 watts; however antenna efficiencies are low, so radiated power was typically much less than 1 watt. Typical transmitting antennae were some form of top-loaded vertical, generally 10 to 15 m high. Receiving antennae were usually an active whip or magnetic loop as these types of antennas appear to be less sensitive to noise pickup. Some experiments using low horizontal dipoles indicated that they perform better than might be expected at MF so that they may prove to be useful aerial for those with sufficient real-estate. Figures 7 and 8 show various transmitter hardware:

Figure 7: Early operation at AX2VKZ showing a 10 watt transmitter and variometer antenna tuning.



Figure 8: The 100 watt 507 kHz beacon transmitter user by AX2VKW.



Household electrical noise was shown to be a significant problem for reception in the 600 m band. Each operator and listener had to address the issue and the problem was solved by applying one or more of the following techniques:

- Installing line filters on noisy appliances.
- Installing a low impedance radio earth.

- Fitting common mode chokes to antenna feed lines.
- Isolated power supplies for receiver pre-amplifiers and active aerials.
- Galvanic isolation of the radio equipment from computers which are used for sound card modes or signal analysis.

Ironically, another big issue was that of interference to the amateur experimenters from numerous AM broadcast stations and Aeronautical Non Directional Beacons (NDB). The problems were caused by receiver frontend overload and intermodulation. A particular problem was around 513 kHz which is a multiple of 9 kHz and many closely spaced carries can be observed on this frequency due to intermodulation effects from the 9 kHz spacing of MF broadcast stations. Similarly, NDBs caused local problems for a number of listeners through overload and intermodulation effects.

1.8 Internet applications

Internet enabled receivers were built and deployed so that the transmitting station could get real time signal reports from distant receiving stations allowing changes to transmitters and antenna systems to be quickly assessed. Such systems also had significant use as propagation reporters as more distant station were seen using such systems. During the experimental operations there were internet enabled receiving stations in New South Wales, South Australia and Tasmania; these stations provided valuable and reliable signal reports.

1.9 Picture transmission

Using the analog picture mode within MFSK16 mode of 'Fldigi'¹ a number of images were transmitted and received over various distances. The picture mode uses no error correction of any sort, simply transmitting the each pixel as a tone. Conditions were not good during the test transmissions, with heavy static due to electrical storms at times, but reasonable images were received.

The images were sent in a bandwidth of approximately 250 Hz. The transmission time for each image is shown for X1 speed; faster speeds can be used if conditions permit (up to X4). Grey-scale images can be sent in one third of the time that colour images take to transmit.

Figures 9 through 12 show various images, their details and reception distances.

The results show that the picture transmission mode could be useful under some circumstances where documents or photographs need to be sent.

Figure 9

40 km

66 x 130 pixels

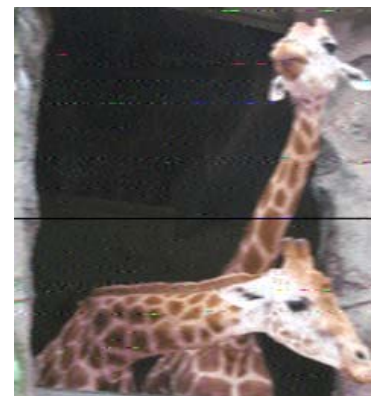
25.7 s



235 x 261 pixels

3 m 4 s

Figure 10



¹ Fldigi is a multifunction software package that provides many 'sound card' modes. It is available from <http://www.w1hkj.com/Fldigi.html>.

Figure 11

410 km

286 x 235 pixels

3 m 21 s

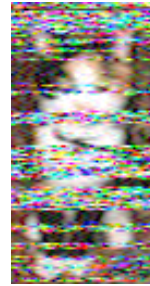


Figure 12

816 km

Details same as

Figure 9



1.10 Field strength measurements

Field strength measurements were undertaken using a loop antenna and Selective Level Meter (SLM). This was done to measure the effective radiated power from a typical amateur station in an urban environment. A 50 watt transmitter feeding a Marconi 'T' antenna was used for the signal source and a Siemens D2055 SLM with an amplified 8 turn loop antenna for reception. The results obtained from the survey are given in Table 2.

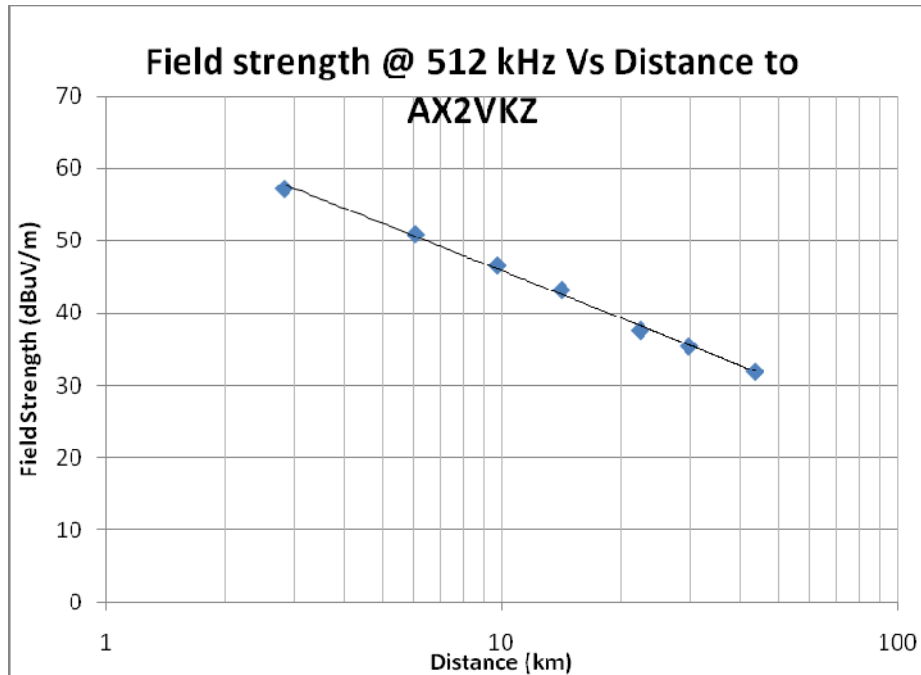
Table 2: Electric field strength vs. distance

Distance (km)	E_f ($\mu\text{V/m}$)	dB ($\mu\text{V/m}$)
2.83	725	57.2
6.07	351	50.9
9.77	214	46.6
14.21	145	43.2
22.45	76	37.6
29.76	59	35.4
43.77	39	31.9

Figure 13: The field strength measurement system.



Figure 14: Field strength from table 2 plotted in decibels referenced to 1 $\mu\text{V/m}$ vs. distance in kilometres.



It is useful to compare the above chart with Figure 6 of the Recommendation ITU-R P.368-9 *Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz*. Using that chart and taking the reading at 10 km for 500 kHz gives a field strength of 87 dB above 1 $\mu\text{V/m}$, that is 41 dB above the reading shown in Figure 14 for the same distance. Noting that the ITU charts assume 1 kW of radiated power, the effective radiated power from AX2VKZ can be calculated to be 0.08 watts. This result can be compared to other methods of calculation.

The RSGB publication *LF Today* (2nd Edition, p101), gives a method to calculate the effective radiated power from the measured electric field strength:

$$P_{erp} = \frac{E_f^2 d^2}{49}$$

Where E_f is the field strength in volts/metre and d is distance in metres. Using the values shown in table 2, the Effective Radiated Power for the test installation was found to be approximately 77 ± 15 mW (one standard deviation), compared to 80 mW calculated using the ITU charts. The theoretical effective radiated power can also be calculated knowing the effective height (h_{eff}) of the antenna and the RF current (I) at its base, 8.5 m and 1.7 amps in this case, which gives:

$$P_{erp} = I^2 160 \pi^2 \left(\frac{h_{eff}}{\lambda} \right)^2 = 0.95 \text{ watts}$$

The measured value is approximately 10 dB below the value calculated above and the difference is thought to be due to the fact that the transmitting antenna was in close proximity to a house, trees and other vegetation. Rough measurements indicated that large RF currents flowed in nearby trees, plumbing and electrical cables when the transmitter was operating. This resulted in a significant amount of power being dissipated in resistive losses which are located well within the reactive near field of the antenna. Commercial MF installations avoid this problem by locating transmitting aerials in clear areas away from buildings and vegetation; they also increase efficiency by installing large low resistance earth systems to reduce loss resistance.

Despite the poor antenna efficiency (0.15 %) and small radiated power, reliable and useful communications was achieved by this station. Such results also show that the ordinary amateur operator would be struggling to approach the 25 W e.i.r.p. limit allowed for the experimental licences and this is an important point to note as this limitation significantly reduces the potential for interference to other services from MF amateur stations.

2. Conclusion

The experimental work undertaken under the licences in the 505-515 kHz band covered a wide range of activities and has shown the utility of the band for amateur communication purposes. The extensive ground wave coverage is different from that of the higher frequency amateur allocations and these characteristics will be very useful for reliable communications when other means are not available.

The lack of directly usable commercial equipment for the 600 m meant that some amateur operators report having rediscovered the technical basis of amateur radio and forgotten skills have been revived, or new skills have been learnt for the first time which can only enhance people's competence; and discovery of new techniques and methods for communications, propagation studies and radio hardware will possibly blossom when more operators have access to the band if it is allocated to the amateur service.